Journal of Nature, Life and Applied Sciences
Volume (4), Issue (2) : 30 June 2020
P: 71 - 80

AJSRP
ISSN: 2522-3356

مجلة العلوم الطبيعية والحياتية والتطبيقية
المجلد (4)، العدد (2) : 30 يونيو 2020م
ص: 71 - 80

# Study the effect of addition Rockwool fibers on the Shielding Radiation for the X-ray of Low Density Polyethylene (LDPE)

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**Abstract:** The extinction of X-rays (radiation attenuation) was studied using the low-density samples of polyethylene polymer to which the rockwool fibers powder is added as filled filler. This latter was blended with (weight percent) and with a micro-filler (filler particle) the sizes equal to or less than<212 µm. Furthermore, the free path average and linear attenuation coefficient were calculated. Experimental results showed that the rockwool fibers powder act to reduce the spaces between polymer chains particularly when the weight percent is more than (10%), which implies the capability of the polymer/filler to make, the X-rays applied to the samples; disappear at these rates used in this study. The experimental work was conducted by applying a radiation beam having an energy of 30 kV based on the use of the X-ray unit with two tubes which are; X-ray generating tube and G-M detector with an energy of $V_{G.M}$ =600. The magnitudes of the mean free path are inversely proportional to the weight percent of the compound material whereas the proportionality of these percentages which are particularly the high ones which occur at experimental values of the linear attenuation coefficient. The value of the mean free path of 1.28 cm is the maximum value obtained at a weight percent of 1 %, whereas the minimum value of the mean path was 0.877 cm at a weight percent of 10 %. In addition, the maximum value of the attenuation coefficient obtained is 4.754 $cm^{-1}$ at a weight percent of 10% and its minimum value at a weight percent of 1% was 0.7 $cm^{-1}$. The maximum value of transmittance and the minimum value of absorbance were obtained at a weight percent of 10%, are (31.8) and (68.2) respectively. Through the practical results that we obtained that are better suited to high percentages more additive proportions can be used than the percentages used in this research to shielding X-rays more.

**Keywords:** Rockwool fibers, Low Density Polyethylene, Shielding radiation.

# دراسة تأثير إضافة ألياف الصوف الصخري على الحجب الإشعاعي للأشعة السينية للبولي اثيلين واطئ الكثافة

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**الملخص:** تمت دراسة حجب الأشعة السينية (توهين الأشعة) باستخدام بوليمر بولي اثيلين واطئ الكثافة المضاف اليه مسحوق ألياف الصوف الصخري وعند حجم دقائق مساو او اقل من (212 μm>) ،و تم حساب معدل المسار الحر ومعامل التوهين الخطي ، ومن خلال ملاحظة النتائج العملية تبين ان مسحوق ألياف الصوف الصخري تعمل على تقليل الفراغات بين السلاسل البوليمرية وخاصة عند النسبة الوزنية (10%) مما يعكس امكانية البوليمر مع المضاف( مسحوق ألياف الصوف الصخري) عند هذه النسبة بحجب قسم كبير من الأشعة السينية المسلطة على النماذج . اذ تمت الدراسة العملية بتسليط أشعة مقدارها (30Kv) وباستخدام وحدة الأشعة السينية (X-ray unit) مع انبوبتي توليد الأشعة ومنظومة كاشف عداد كايكر –ميلر( G-M detector) وبطاقة مقدارها ($V_{G.M}$ =600 volt). ووجد من خلال النتائج العلمية التي تم الحصول عليها من البحث نستنتج بأن قيم معدل المسار الحر تتناسب تناسبا عكسيا مع النسب الوزنية للمادة المتراكبة وان القيم العملية لمعامل التوهين الخطي( μ) تتناسب تناسبا طرديا مع النسب الوزنية للمادة المتراكبة وخاصة عند النسب الوزنية العالية، وتم الحصول على اعلى قيمة لمعدل المسار الحر عند النسب الوزنية (1%) وهي (1.42 cm) بينما كانت اقل قيمة لمعدل المسار الحر هي (0.877 cm) عند النسبة (10%) . كما تم الحصول على اعلى قيمة لمعامل التوهين الخطي وهي ($4.754\ cm^{-1}$) عند النسبة (10%) واقل قيمة كانت عند النسبة (1%) وهي ($0.7\ cm^{-1}$)، كما تم الحصول على اقل قيمة نفاذية واعلى قيمة امتصاصية عند النسبة (10%) وهي (31.8) و (68.2) على التوالي. من خلال النتائج العملية التي حصلنا عليها والتي تكون ملائمة بشكل أفضل مع النسب العالية يمكن استخدام نسب أكبر للمضاف من النسب المستخدمة في هذا البحث لحجب الأشعة السينية بشكل أكبر.

**الكلمات المفتاحية**: الصوف الصخري، البولي اثيلين واطئ الكثافة، الحجب الإشعاعي.

## 1- Introduction

Polyethylene is one of the types of polymers. Divides the polyethylene into two main parts depending on the density, low-density polyethylene (LDPE) and high-density polyethylene (HDPE) [1,2,3]. Low-density Polyethylene is produced by polymerization under high pressure of gas ethylene. LDPE is a partially crystalline solid, density (0.91 – 0.94 g/cm$^3$), proportion of crystallization be (50 – 60 %) and dissolves in the organic solvents above the ( 100 ºC) [4]. Low-density Polyethylene (LDPE) is the non-toxic materials that are used in the industrial applications[5]. LDPE is one of the materials famous commercially on the widely range [6]. The composites of low-density polyethylene are used in different applications, as materials in the cars industry, also as packaging film and window frames [7,8,9].

Fillers are either organic or inorganic, which can be added to polymeric materials to enhance the mechanical, thermal and electrical properties of polymers [10,11]. When fillers are added, the final cost of produced polymers decreases. Polyethylene low density composites are used in automobile industry as well as in a range of daily tools such pipes, packaging film, tubes and window frames [12,13,14,15,16,17].

Polymeric substances which have appropriate neutron attenuation can be generally used as proper alternatives for protecting of γ-radiation and X-rays utilizing several additives such as minerals or heavy metals. Many scientists have improved some polymer composites specifically for their radiation shielding features. Low density polyethylene has mixed with hollow glass spheres. The LDPE has supplied protection of radiation and glass spheres have led to enhance the modulus with using minimal weight gain [18,19]. In this work, rockwool fibers powder composites have been added to low density polyethylene to shield the spread of x-ray radiation through the polymer matrix.

## 2- Experimental

### 2.1 Materials

1- Low density polyethylene (SCILEN 22004) grade supplies from the state company for the Petrochemical Industry (SCPI) in Basra/Iraq has melt index =0. 39 g/10min., density = 0.922 g/cm$^3$.

2- Rockwool, as a filler which supplied by that-alsawwary company in Baghdad/Iraq. The average Rockwool fibers particle size used in this work is (<212)µm. The chemical composition Rockwool is shown in table (1).[20,21]

**Table (1) The chemical composition of Rockwool**

| Chemical composition | $SiO_2$ | $Al_2O_3$ | $Fe_2O_3$ | CaO | MgO | $Na_2O$ | $K_2O$ |
|---|---|---|---|---|---|---|---|
| wt.% | 43.54% | 15.01% | 10.82% | 11.82% | 4.51% | 0.14% | 14.16 |

### 2.2 Sample preparation

In this study, five weight percents of Rockwool fibers (1, 2.5, 5, 7.5and 10) % were used to prepare the polymeric composites. Rockwool powder is mixed with LDPE using Rheomix mixer with over 600 instruments attached to the Haake Rehochard meter (United States of America)with the following conditions; mixing time 15 min; mixing temperature 160$^0$C ; mixing velocity 32 RPM. After that the final mold product is introduced in a laboratory compress (Iraq/Basra) under 5 tons at 175$^0$C for 3 minutes in a square frame where the pressure rises gradually up to 15 tons for (6) minutes and after this period the sample sheet is cooled up to reach room temperature. The dimensional model (20X20)cm is then pulled into a shredder(Automatic Hollow Diepunch-code 6050). The models are cut off using the machine or can be manually cut according to the dimensions of the sample used in the radiation blocking measurements with a thickness (2.4mm) .

### 2.3 Attenuation measurement

The high voltage of an x-ray type (LEYBOLD-HERAEUS) device was set up using a small lever, where the voltage of the device (30 KV) and the operating voltage of the gas detector (600 volt), and the time of each reading were adjusted to be one minute (60 sec) for each reading. The direct is recorded without any means of absorption (without any slice) is called (Io). The samples are then taken from the polymer, that the rockwool powder is added to it directly, in face the X-ray beam which is produced by the generating unit. (2.4 mm) between the X- ray generator and the gaseous detector (Geiger-Muller counter). Three readings are taken and then the reading rate is recorded called ($I_{a.v}$) which represents the transmitted ray through the thickness. This process is repeated for more than one slice of the sample under measurement and thus the transmitted ray is recorded for each thickness ($I_{a.v}$ is measured in the presence of samples for each weight ratios added from the blending of polymer and additives) that is depicted as in Fig. 1 which represents a photographic image of the X-ray generator used in this work.


**Figure (1) The instrument (LEYBOLD-HERAEUS ) used in the measurement.**

### 2.4 Mathematical side

When a beam of x-ray any kind penetrates matter some passes through an Attenuator, may be absorbed completely, some may be scattered and some may pass straight through without any interaction at all can be calculated by the following formula:

$$-\mathrm{d}I/I \ \alpha \ \mathrm{d}x \quad \text{.........} (1)$$

$$\mathrm{d}I/I = -\mu \ \mathrm{d}x \quad \text{.........} (2)$$

The integration of this on all the value (dx) in which the intensity of ($I_o$) to (I) can be obtained finding a constant proportionality (μ), which is:

$$\int_{I_o}^{I} \frac{\mathrm{d}I}{I} = -\mu \int \mathrm{d}x \text{.........} (3)$$

Where I is the intensity outside of a shield of thickness, $I_o$ is the unshielded intensity μ is the linear attenuation coefficient of the shielding material X is the thickness of shielding material.

From equation (3) can be obtained the by the following:

$$\mu = (Ln(Io/I))/X \quad \text{.........} (4)$$

$$\lambda = 1/\mu \quad \text{.........} (5)$$

Where λ is known as the attenuation length or mean free path. It is the average distance travelled by a photon before it is absorbed. The distance over which one-half of the initial beam. Its absorbed is called the half thickness x1/2. It is related to the linear attenuation coefficient and the mean free path by

$$X_{1/2} = Ln(2)/\mu \quad \text{.........} (6)$$

## 3- Result and Discussion

In Fig. 2, the relationship of the mean free path (λ) which is calculated by Eq. 5 and it directly depends on linear attenuation coefficient (μ) values with the weight ratios of the overlapping material. Furthermore, the decrease in the behavior of the mean free path occurs when the weight ratios are increased particularly at the high ratios (10% and 5%) which mean there is an inverse relationship between the high ratios of the additive (rock wool fibers powder) and the mean free path. As shown in Fig. 2, when ratios of the overlapping material increase, the decrease will occur in the rate of distance travelled by the photon before removing from the beam by absorption or scattering. This means that the density of the sample at the high ratios (10% - 5%) is large and, thus, the movement numbers of the photons are constrained and low leading to increase the values of the linear attenuation coefficient. Therefore, it results in a decrease in the mean free path. Furthermore, this is obtained with a higher value from Fig. 2 at weight ratio of (0%) that is equal to (2.38cm) as in Table (2). In the weight ratio (1%), the value was (1.428 cm), while the lowest value was (0.877cm) at weight ratio (10%).

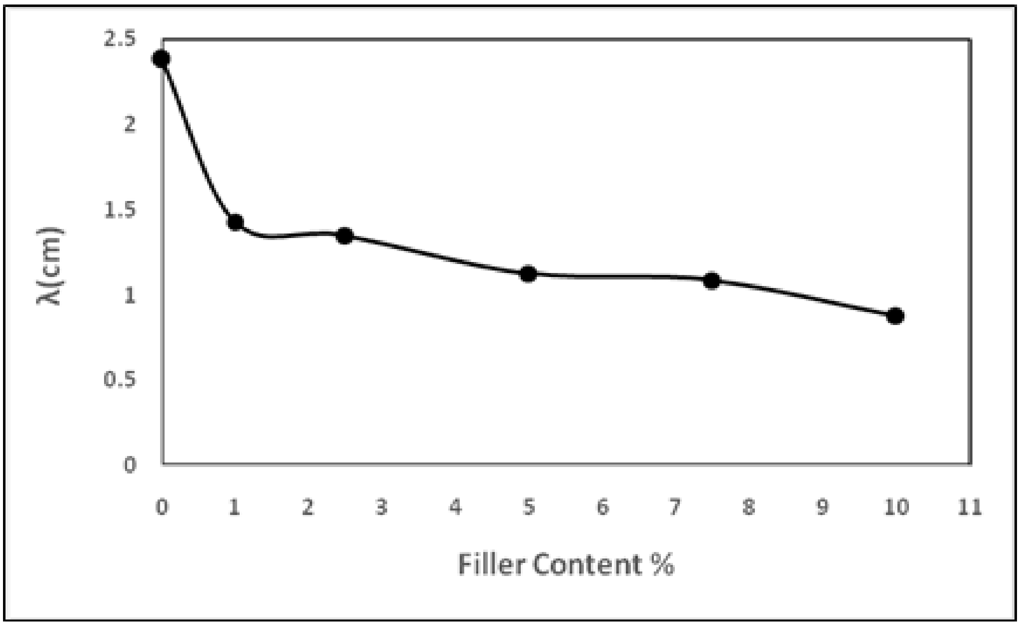



**Figure (2) Variation between mean free path and Filler content (wt.%).**

The relationship between, the linear attenuation coefficient, which is calculated from Eq. 4 depending directly on the values of transmitted radiation intensity, and the weight ratios of the overlapping material (rock wool fibers powder) is depicted in Fig. 3. From this latter, a higher value of the linear attenuation coefficient is obtained which is equal to 4.754 $cm^{-1}$ at weight ratio of (10%), whereas, the lowest value was 0.420 $cm^{-1}$ at weight ratio of (0%) and then 0.700 $cm^{-1}$ at weight ratios of (1%). In Fig. 3, it can be observed that the attenuation factor behavior is increased as the weight ratios increase particularly at a high ratio (10%). This means, there is a direct correlation between the high rates of the additive (rock wool fiber powder) and the linear attenuation coefficient leading that the additive at these percentages act to increase the surface boundary of the model and then increasing its density (presence of a strong homogeneous between the polymer and the additive at these percentages). Consequently, when the applied radiation beam $I_o$ hits the sample, some of the photons will vanish from the beam (disappear and diminish) into the sample leading probability of large scattering and multiply the photons to occur.

Thus, the possibility of extraction some of the photons can completely occur and hence, a part of the beam will be transmitted through the sample (I). Accordingly, a large part of the beam at these weight ratios cannot pass through the sample to the other side due to the uniform distribution of the additive with polymer molecules which is diffused throughout the polymer without any accumulation in a certain region than other.

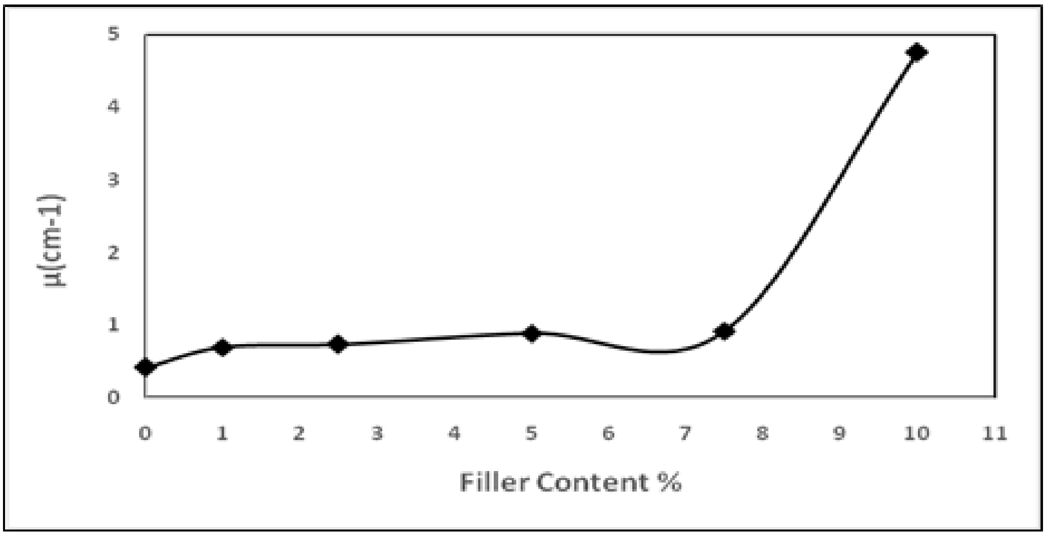



**Figure. (3) Variation between linear attenuation coefficient and Filler content (wt.%).**

Figure 4 shows the relationship between the transmittance and the weight ratios of the overlapping material. As can be seen from Figure 4, the reduction in transmittance ratio occurs as the weight ratios are too high particularly at the high ratio of 10% where its value is equal to 31.8. This means, there is an inverse relationship between the transmittance and the high percentages of the additive (rock wool fibers powder). The higher the ratio occurs, the better the attenuation of the radiation is obtained. This is due to the homogenous distribution of the polymer with additive and the latter act as a barrier which prevents the radiation to be greatly passed through the polymer. In fact, this is our aim from this paper that includes the minimization, disallow and attenuation a large part of the radiation to transmit and pass to the other side through the sample.

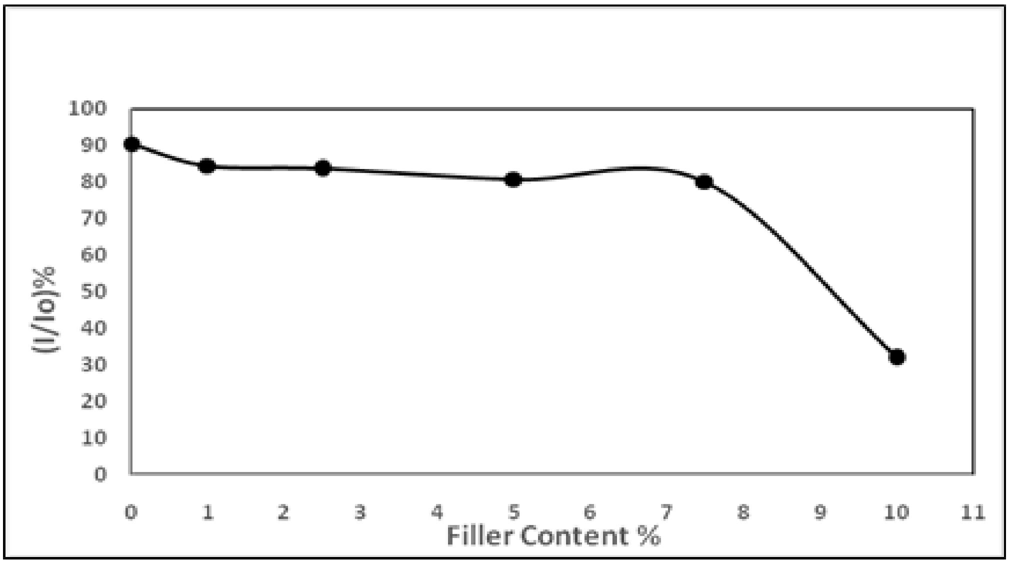
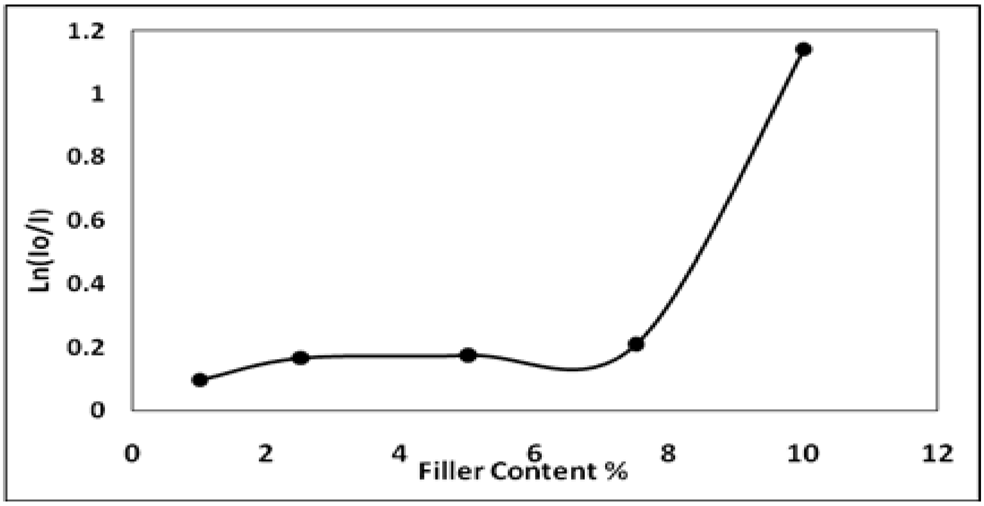



**Figure (4) Variation between transmittance and Filler content (wt.%).**

Figure (5) shows the relationship between the logarithm of the absorbance coefficient and the weight ratios of the overlapping material (polymer plus rock wool fibers powder). In this figure, it can observe that as the behavior of a composite of filler increases, the weight ratios will increase particularly at 10%. This means that the behavior depends completely on the intensity of the transmitted radiation (I). The minimum coefficient of absorption leads to an increase in behavior and vice versa. The values of the radiation transmitted at the high ratios are small due to both polymer and additive absorb the largest part of the radiation and block it to be pass to the other side. This leads the logarithm values of absorption coefficient to decrease and when the weight ratios are small, the values of the transmitted radiation become large that means the sample allow more of radiation to be passed to the other side leading to increase in the logarithm of the absorption coefficient.




**Figure(5) Variation between logarithm absorption and Filler content (wt.%).**

**Table (2) Parameters of shielding radiation**

| Filler content (wt.%) | Attenuation coefficient ($cm^{-1}$) | mean free path (Attenuation length)(cm) | Transmittance% | Absorption % | ln( $I_o/I$) |
|---|---|---|---|---|---|
| 0 | 0.420 | 2.380 | 90.4 | 9.6 | 0.098 |
| 1 | 0.700 | 1.428 | 84.4 | 15.6 | 0.166 |
| 2.5 | 0.740 | 1.351 | 83.6 | 16.7 | 0.176 |
| 5 | 0.887 | 1.127 | 80.7 | 19.3 | 0.211 |
| 7.5 | 0.919 | 1.088 | 80.1 | 19.9 | 0.218 |
| 10 | 4.754 | 0.877 | 31.8 | 68.2 | 1.141 |

## 4- Conclusion

The study has been investigated that the rock wool fibers powder added to low-density polyethylene particularly at the high ratios, has a blocking effect on the applied X-rays which its value is equal to ($I_o$ = 39748). This means the high ration is appropriate for the sample to be a useful manner in blocking the X-ray resulting that there is an inverse relationship between high ratios of additive and mean free path ($\lambda$), whereas, there is a direct correlation between high ratios of the additive and the linear attenuation coefficient ($\mu$). Thus, the ratio (10%) is the best ratio compared to the other in terms of their ability to block the applied X-ray.

## 5- Recommendations

1- Using rock wool as an additive with low density polyethylene to block X-rays.
2- Using high levels of additive (rock wool) to block larger x-rays.
3- Use plates of different thicknesses to know their ability to block X-rays.
4- Manufacture of polymeric panels (low density polyethylene, and rock wool) and their application in the field of medicine, atomic energy, and industry that requires radiological shielding, especially in the field of X-ray, widely used in hospitals.

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